PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
P/31800/VISD		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/GB 00/01979	24/05/2000	24/05/1999
Applicant		
MARCONI APPLIED TECHNOLOGIES LIMITED		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 6

   [X] as suggested by the applicant.

   [ ] because the applicant failed to suggest a figure.

   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/01979

A. CLASSIFICATION OF SUBJECT MATT[redacted]
IPC 7 G02F1/03 G0[redacted]/055 H04N5/335

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02F H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 335 939 A (STOVELL JOHN E ET AL) 22 June 1982 (1982-06-22) abstract column 1, line 43 -column 3, line 57; figures 8,9,12,13	1-4,6-8, 11,12, 16,17, 19,20, 25,26
A	---	10,15
X	US 5 305 136 A (SMITH) 19 April 1994 (1994-04-19) column 1, line 7 - line 13 column 4, line 7 -column 9, line 64	1-3,6-8, 11,12,26
A	---	4
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed. invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 September 2000	15.05.01

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	BADICS

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/01979

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 919 522 A (NELSON BRUCE N) 24 April 1990 (1990-04-24) abstract column 5, line 26 -column 8, line 68	1-3,6, 11,12, 14,19

X	US 4 439 014 A (STACY ROBERT A ET AL) 27 March 1984 (1984-03-27) column 1, line 63 -column 2, line 2 column 2, line 41 - line 52 column 3, line 48 -column 5, line 57; figures 2,3	1,2,7,11
Y		9,13,15, 23
A		15,22, 25,26

Y	CH 500 501 A (UNITED STATES ATOMIC ENERGY COMMISSION) 29 January 1971 (1971-01-29) column 9, line 36 -column 12, line 52; figure 1	9,13,15, 23
A		1,8,16, 17,21, 25,26

Y	PATENT ABSTRACTS OF JAPAN vol. 1997, no. 1, 31 January 1997 (1997-01-31) & JP 08 250692 A (SHARP CORP.), 27 September 1996 (1996-09-27) abstract	23
A		1

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 00/01979

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 4335939	A	22-06-1982	DE	3013498 A	30-10-1980
			GB	2046937 A,B	19-11-1980
			JP	55153440 A	29-11-1980
US 5305136	A	19-04-1994	NONE		
US 4919522	A	24-04-1990	NONE		
US 4439014	A	27-03-1984	NONE		
CH 500501	A	15-12-1970	DE	1945755 A	02-04-1970
			FR	2017817 A	22-05-1970
			GB	1277109 A	07-06-1972
			JP	49007167 B	19-02-1974
			SE	364572 B	25-02-1974
			US	3531182 A	29-09-1970
JP 08250692	A	27-09-1996	NONE		

PATENT COOPERATION TREATY

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REC'D 05 SEP 2001
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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
P/61800/VISD		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/01979	24/05/2000	24/05/1999
International Patent Classification (IPC) or national classification and IPC G02F1/03		
Applicant MARCONI APPLIED TECHNOLOGIES LIMITED		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 10 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

I	☒	Basis of the report
II	☐	Priority
III	☒	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	☐	Lack of unity of invention
V	☒	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
VI	☐	Certain documents cited
VII	☒	Certain defects in the international application
VIII	☒	Certain observations on the international application

Date of submission of the demand	Date of completion of this report
20/12/2000	03.09.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Noirard, P Telephone No. +49 89 2399 2420

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/01979

I. Basis of the report

1. With regard to the elements of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-16 as originally filed

Claims, No.:

1-26 as originally filed

Drawings, sheets:

1/6-6/6 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

1. The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been examined in respect of:

   ☐ the entire international application.

   ☒ claims Nos. 25,26.

because:

   ☐ the said international application, or the said claims Nos. relate to the following subject matter which does not require an international preliminary examination (*specify*):

   ☒ the description, claims or drawings (*indicate particular elements below*) or said claims Nos. 25,26 are so unclear that no meaningful opinion could be formed (*specify*):
   see separate sheet

   ☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed.

   ☐ no international search report has been established for the said claims Nos. .

2. A meaningful international preliminary examination cannot be carried out due to the failure of the nucleotide and/or amino acid sequence listing to comply with the standard provided for in Annex C of the Administrative Instructions:

   ☐ the written form has not been furnished or does not comply with the standard.

   ☐ the computer readable form has not been furnished or does not comply with the standard.

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

   Novelty (N) Yes: Claims 14,18,20,21

	No:	Claims	1-13,15-17,19,22-24
Inventive step (IS)	Yes:	Claims	
	No:	Claims	14,18,20,21
Industrial applicability (IA)	Yes:	Claims	1-24
	No:	Claims	

2. Citations and explanations
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

R Item III

Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

Claims 25 & 26 consist of references to the description and the drawings and do not define any clear technical feature of the claimed device. According to Rule 6.2(a) PCT, claims should not contain such references except where absolutely necessary, which is not the case here.

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive st p or industrial applicability; citations and explanations supporting such statement

Due to the great number of lack of clarity objections raised against the claims, the applicant is asked to read item VIII, first.

1.1 Reference is made to the following documents :

D1: US-A-4 335 939 (STOVELL JOHN E ET AL) 22 June 1982 (1982-06-22)

D2: US-A-5 305 136 (SMITH) 19 April 1994 (1994-04-19)

D3: PATENT ABSTRACTS OF JAPAN vol. 1997, no. 1, 31 January 1997 (1997-01-31) & JP 08 250692 A (SHARP CORP.), 27 September 1996 (1996-09-27)

D4: US-A-4 919 522 (NELSON BRUCE N) 24 April 1990 (1990-04-24)

Note: The references in brackets {..} relate to passages in the present application.

1.2 Negative statements : claims 1-13,15-17,19,22-24 lack novelty (Article 33(2) PCT), and claims 14,18,20,21 lack an inventive step (Article 33(3), PCT).

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2. The subject matter of independent claim 1 lacks novelty (Article 33(2) PCT) having regard to the teaching of any of the documents D2-D3 for the following reasons :-

2.1 Document **D1** discloses an electro-optic device (cf. Figs. 4,8,9,12) comprising a polarising beam splitter (1) which produces two differently polarised components propagating along two optical paths and birefringent cell means (2,18,19). Therefore, independent **claim 1** is not new.

The following additional features are also present in **D1**:
* two different cells in the two paths {**claim 2**} : see Fig. 9 and column 7, lines 1-4;
* a single cell for both paths {**claim 3**} : see Fig. 8 and column 6, lines 44-45;
* first and second paths kept separate {**claim 6**} : see Fig.12, where beams 20 & 21 fulfil this requirement;
* first and second paths combined {**claim 7**} : see Fig. 8 and column 6 lines 45-49;
* optical sensor means located "after the first and second paths" (cf. item VIII, §1) {**claim 8**}: see Fig. 12 the sensors 38, 39; the same disclosure where, in addition, the combination of the sensors is achieved in the feedback circuit 41 in Fig. 12 of D1, anticipates also present **claim 10**;
* an analyser means following the birefringent cell means along the optical path {**claim 11**} : see the Glan prism 17, Fig. 8 and column 6, lines 50-59;
* the beam splitter is a polarising beam splitter cube {**claim 12**} in Fig. 8 in D1 (see ref. 1);
* the birefringent cell includes PLZT material {**claim 13**} : see column 5, lines 3-5 and lines 60-63;
* the cell means is operable to produce three or more transmission levels {**claim 15**} : see Fig. 9 and column 7, lines 53-55, where the continuous range of modulation involve (at least) three transmission levels;
* a control means applied to the cells to control the optical intensity outputted by the device {**claim 16**} : see Fig. 12 and column 9, lines 22-35; and wherein the light transmitted is monitored by sensors {**claim 17**} : see the photodetectors 38 and 39;
* the optical axis of the cell is rotated between both paths {**claim 22**} : see Fig. 4 and column 5, lines 23-37.

Therefore, respective dependent claims are anticipated.

2.2 Document **D2** also discloses an electro-optic device (cf. Figs. 1,1A) comprising a polarising beam splitter (16) which produces two differently polarised components propagating along two optical paths (38, 40) and birefringent cell means (24, 24A, 24B). So D2 also anticipates **claim 1**.

Furthermore, this disclosure also removes novelty of claims **2** (cf. Fig.1A), **3** (cf. Fig.1), **6** (cf. ref. 15A, 50A), **7** (cf. ref. 16A), **8** (cf. ref. 52, 52A), **11** (cf. ref. 16A), and **12** (cf. ref. 16).

2.3 Document **D3** also discloses an electro-optic device (cf. Figs. 1,4,6,7) comprising a polarising beam splitter (cf. the "polarized light separation device" 30) which produces two differently polarised components propagating along two optical paths (cf. Fig. 6) and birefringent cell means (31,32). So D3 also anticipates **claim 1**. Document D3 also shows a single cell (31 or 32) {**claim 3**} or a plurality of birefringent cells in cascade in the paths (cf. fig. 6, ref. 311,312,313) {**claim 5**}, which cells are independently controllable (cf. Fig. 7) {**claim 4**}. Further, the paths are kept separate (see Fig.6) {**claim 6**}, and the optical sensor (cf. ref. 5, Fig. 1) {**claim 8**} is a CCD {**claim 9**}. Fig. 12 teaches three or more "degrees of transmission" through the cell 12 {**claim 15**}, and Fig. 11 shows the beam splitter (30) and the cells (31 and 32) integrated in a single component {**claim 19**}. Finally, Fig. 1 of **D3** teaches to include the electro-optic device in a camera apparatus (see the part "purpose" in the abstract) {**claim 23**} and particularly in its focusing system (see Fig. 1) {**claim 24**}.

3. Apart from the fact that the subject matter of dependent claims 5, 9, and 19 is anticipated by **D3** (see §2.3, above), it also cannot be considered as involving an inventive step (Article 33(3) PCT) for the following reasons:-

Hereafter, document **D1** will be considered as closest prior art, which features in common with the claims have already been listed in §2.1, above.

* The feature of **claim 5** to add a plurality of birefringent cells in cascade is suggested in **D1** (see from column 7 line 65 to column 8, line 3, in relation with Fig. 10) as well as in **D2** (cf. column 3,. lines 31-36).

* Using CCD as particular choice of sensor is common in the art of optical sensor {**claim 9**}.

* Document **D4** shows in Fig. 5 and therefore suggests to the skilled person how to integrate the electro-optic device into a single component (comment: D4 fails to disclose the polarising beam splitter, but discloses instead a beam splitter 50 and two polarisers 49 and 54), thus, **claim 19** is not inventive.

4. Following the clarity objections raised against **claims 14, 18, 20, and 21** (see item VIII, below), it is at present not possible to extract additional features from the present wording of these claims that can render their subject matter inventive.

5. The industrial applicability (Article 33(4) PCT) is clearly present for the subject matter of all the claims.

Re Item VII

Certain defects in the international application

1. Independent claim 1 is not in the two-part form in accordance with Rule 6.3(b) PCT, which in the present case would be appropriate, with those features known in combination from the closest prior art being placed in the preamble (Rule 6.3(b)(i) PCT) and with the remaining features being included in the characterising part (Rule 6.3(b)(ii) PCT).

2. The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

3. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the cited documents **D1-D4** is not mentioned in the description, nor are these documents identified therein.

4. The requirement of Article 5 PCT, that the description shall disclose the invention in a manner sufficiently clear and complete is not fulfilled in view of the following point:-
   * in the part "description of the drawings" {cf. page 8}, Figures 1 and 2 should have been mentioned;
   * in Fig. 7a & 7b, the legend and tics of the vertical axis appear not to be consistent;
   * Fig. 8c and corresponding comments on page 13 lines 7-9 are unclear.

Re It m VIII

Certain observations on the international application

Certain claims do not meet the requirement of Article 6 PCT in that the subject matter for which protection is sought lacks clarity or is not fully supported by the description for the following reasons:-

1. Claim 1 introduces the feature of "optical path" which corresponds to the immaterial and not ending path followed by the light passing into the electro-optic device. As a consequence, it is of obscure scope to define the "optical outputs of the ... paths", as well as to state "after they have travelled along the paths". Hence the subject matter of **claims 6, 7, 8 10, and 11** lacks clarity.
   Furthermore, concerning the "output" and "optical output" introduced in **claims 16, 17, 18**, they apparently do not correspond to the same "output" location as defined in claims 6,7.. and thus render the subject matter of these claims unclear.

2. Since **claim 3** claims a single cell, it cannot be made dependent on claim 2, which claims two "different cells". A similar lack of clarity applies also to the subject matter of **claims 4, 5, 14, and 22** when made dependent on claim 3 (i.e. the single cell).

3. The subject matter of **claim 4** is unclear because it is stated that the cell means is "controllable" without specifying which parameter is controllable. However, in this report, it has been assumed that the effective birefringence of the cell is controllable.

4. It is clear from the description {cf. page 6, lines 4-7} that the plurality of birefringent cells stated in **claim 5** relates to birefringent cells in cascade in the first and second paths. Since this feature is essential for the definition of the subject matter of this claim, it should have been added.

5. In **claim 11** it is unclear what kind of analysis the "analyser" performs. However, it has been assumed that this claim deals with a polarisation analyser.

6. In **claim 14**, the layout disclosed {i.e. that the electrodes of the first cell are offset with respect to the electrodes in the second cell}, is not clear enough to define precisely the scope of protection because it depends on the (unknown) location of the cells.

7. In **claim 16**, the "predetermined range" stated is of obscure scope. Furthermore, this apparatus claim relates to a method of using the apparatus rather than clearly defining the apparatus in terms of its technical features. The intended limitations are therefore not clear from this claim. This later objection holds also for the subject matter of **claim 18**.

8. Since common sensors do not present a "frame interval", the subject matter of **claim 18** that introduces the "frame intervals of a sensor" is unclear.

9. **Claims 19, 20** do not meet the requirements of Article 6 PCT in that the matter for which protection is sought is not clearly defined. The functional statements stated (even when read in the light of the corresponding part in the description {apparently Fig. 14a}) do not enable the skilled person to determine which technical features are necessary to perform the stated functions.

10. The subject matter of **claim 21** is unclear and is defined in terms of the result to be achieved. The intended limitations are therefore not clear from this claim.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 November 2000 (30.11.2000)

PCT

(10) International Publication Number
WO 00/72079 A2

(51) International Patent Classification[7]: G02B 27/00

(21) International Application Number: PCT/GB00/01979

(22) International Filing Date: 24 May 2000 (24.05.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
9912072.7 24 May 1999 (24.05.1999) GB

(71) Applicant *(for all designated States except US)*: MARCONI APPLIED TECHNOLOGIES LIMITED [GB/GB]; One Bruton Street, London W1X 8AQ (GB).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: SPENCER, Simon, Howard [GB/GB]; "Padarn", Hopping Jack's Lane, Danbury, Chelmsford, Essex (GB). PRITCHARD, William, Philip [GB/GB]; 39 Woodhall Road, Chelmsford, Essex CM1 4AE (GB).

(74) Agent: COCKAYNE, Gillian; Marconi Intellectual Property, Waterhouse Lane, Chelmsford, Essex CM1 2QX (GB).

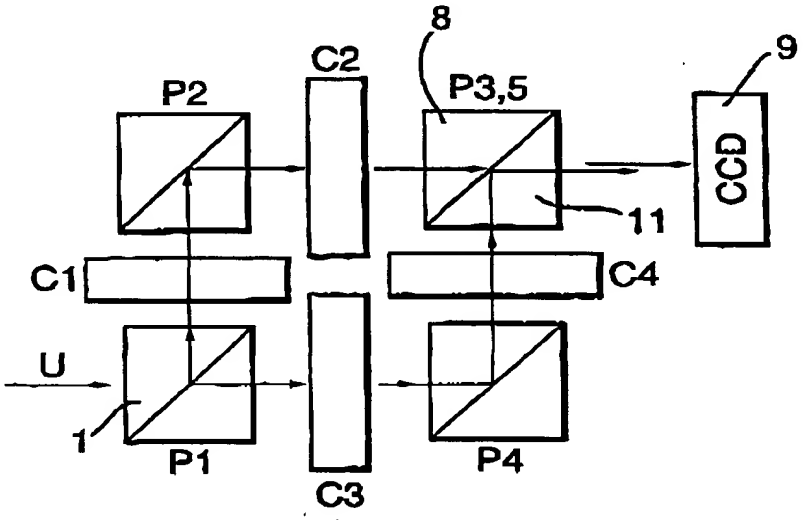
(81) Designated States *(national)*: JP, US.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published:
— *Without international search report and to be republished upon receipt of that report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: ELECTRO-OPTIC DEVICES



(57) Abstract: An electro-optic device includes a polarising beam splitter (1) which sends a polarised component along a first path via birefringent cells (C1 and C2) and a differently polarised component via a second path through cells (C3 and C4). The two components are combined at 8 and the output directed onto a CCD sensor (9). The modulator has high transmission characteristic and allows faster switching. In one embodiment, the device is used to view differently polarised light from a scene.

WO 00/72079 A2

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09/926592

WO 00/72079 PCT/GB00/01979

JC19 Rec'd PCT/PTO 23 NOV 2001

ELECTRO-OPTIC DEVICES

This invention relates to electro-optic devices such as, for example, modulators or shutters which use birefringent material.

In these types of electro-optic devices, the application of an electrical field to the material causes its effective birefringence to change, resulting in rotation of its optic axis. This effect may be used to modulate incident optical radiation. Figure 1 illustrates a known simple electro-optic shutter configuration which comprises three elements, an input polariser P1, a birefringent cell C1 and an output analyser P2 (usually a second polariser). The birefringent cell C1 includes electrodes on its major surfaces to enable an electrical field to be produced in the cell C1 when a potential difference is applied across the electrodes. The shutter as illustrated in Figure 1 is subjected to unpolarised input radiation U which is incident on the input polariser P1. The light transmitted by input polariser P1 is linearly polarised and is incident on the cell C1. For zero field conditions, the state of the linearly polarised light is not altered as it passes through the electro-optic element and the light is absorbed by the second polariser P2 which is crossed relative to the input polariser P1. When a voltage is applied across the cell C1, it acts as an optical retarder, shifting the relative phases of light polarised parallel and perpendicular to the applied electric field. Thus linearly polarised light received at cell C1 is changed to elliptically polarised light at its output, a portion of which will pass through the second polariser P2. The transmissivity in the on-state may be maximized by adjusting the electric field such that the birefringent cell C1 behaves as a half-wave retardation plate, such that light is

linearly polarised at the output of the cell C1 with the plane of polarisation being rotated by 90°.

The performance of a shutter can be characterized by a number of performance parameters and the most suitable selected for a particular application. These parameters include the transmission (T_{ON}), extinction (T_{OFF}), response time (t_r), repetition rate (f_r), acceptance angle, power consumption and the spectral range over which the shutter is effective.

Figure 2 illustrates another optical shutter which has improved extinction, acceptance angle and power consumption compared to the shutter shown in Figure 1. In the Figure 2 device, two birefringent cells C1 and C2 are spatially arranged alternately along the optical path with three polarisers P1, P2 and P3. If the two cells C1 and C2 are each identical with the single cell C1 of the Figure 1 device, the same effect can be achieved at the output using approximately half the voltage applied across each of the cells. Thus, if say in the Figure 1 device, voltage pulses of 600V were applied across the cell C1 to switch it between states, in the device of Figure 2 each cell C1 and C2 is subjected to pulses of 300V, leading to a faster response time and increased repetition rate. Other improvements may be achieved by including coatings on the surfaces of the optical elements and by appropriate selection of the chemical composition of the birefringent material.

According to the invention there is provided an electro-optic device comprising: a polarising beam splitter which produces first and second differently polarised

components from applied unpolarised optical radiation; first and second optical paths along which the first and second components respectively are directed; and birefringent cell means in the first and second paths.

A device in accordance with the invention may have a significantly higher transmission characteristic than previously known devices. By sending the first and second components along what are effectively parallel optical paths, both of these components obtained from the original unpolarised incident radiation are utilized in the device. In the devices as illustrated in Figures 1 and 2, the initial polariser cuts down transmission through the system as a whole by 50% at least, with other components in the optical path adding to the reduction in transmission. The significantly improved transmission obtainable by making use of the invention means that devices based on the electro-optic effect become practicable in applications for which previously they would not have been considered. A device in accordance with the invention does not require a collimated, polarised or monochromatic illuminant source in order to work.

For a typical device, a prior art arrangement such as that shown in Figure 1 may have a transmission of approximately 42% whereas in a comparable device in accordance with the invention, transmissions of 80% may be achieved.

The term "optical" as used in this specification is intended to cover not only the visible parts of the spectrum but also the ultra-violet and far infra-red ranges also. For a particular device, the components included must be optimised for the parts of the

spectrum at which it is intended to operate.

A device in accordance with the invention may be used as a shutter in applications such as for example gated TV cameras (which may use CCD or other solid state sensors), laser gated TV cameras, multicolour cameras and displays, holographic displays, mid-infra-red range thermal cameras (operating at wavelengths of 3 to 5 microns for example), and thermal modulators for thermal cameras.

A device according to the present invention may be used as a voltage controlled attenuator. A varying voltage may be applied to the birefringent cell means to control transmission through the device. Thus where the output of the device is directed onto a sensor, the transmission may be controlled such that the sensor is operated at its optimum level of incident light. The transmission may be controlled using a separate circuit but in one advantageous embodiment, a control signal is derived from a sensor receiving the output from the device. For example, a CCD sensor output may be used to provide a feedback signal for the birefringent cell means. The device may be used to control light transmission where the output is to be received in turn by different sensors having different characteristics and/or where the input optical radiation to the device has changing characteristics, for example to view a scene under daylight conditions and also at night when illuminated by a laser source.

Where the device is used to deliver light from a scene to a sensor, such as a CCD sensor, there may be occasions where a bright point source in the scene causes an undesirable voltage spike at the output of the sensor during frame intervals. By

controlling transmission through the device, this may be avoided by ensuring that the device is non-transmissive during the frame intervals. This may be done for all frame intervals during normal operation as a precaution or only when conditions are such that a voltage spike is generated.

The invention is applicable to any device which uses the birefringence effect. For example, the birefringent cell means may comprise a Pockel cell or cells, Kerr cell or cells or LCD cells.

A particularly suitable material for use in a birefringent cell means is lanthanum-modified lead zirconate titanate (PLZT). Such materials may be tailored so as to control the magnitude of the birefringence for example by adjusting the percentage of lanthanum included in the material.

In a preferred embodiment, the cell means comprises a first cell in the first path and a second different cell in the second path. However, in an alternative embodiment, the cell means may comprise a single cell which is included in the both the first and second paths, the first and second components being applied to different regions of the single cell.

The polarising beam splitter may comprise a polarising separator such as a polarising beam splitter cube. In a preferred device, the polarising separator is such that it produces a transmitted component in one direction and a reflected component at 90^0 to the transmitted component, with the first and second components being linearly

polarised in different directions. Other cubes are available which produce transmitted and reflected components separated by other angles, for example 45^0. For example a Glan-Thompson polarizer gives 40^0.

In a preferred embodiment of the invention, the cell means includes a plurality of birefringent cells in the first path and a plurality of birefringent cells in the second path. By cascading the cells in each path, increased transmission, repetition rate and switching speeds are achievable.

In one embodiment the optical outputs of the first and second optical paths are kept separate. These outputs may be separately processed subsequently or may be combined following conversion from optical form into, say, electrical signals. For example, a first CCD sensor may receive the optical component from the first path and a second CCD sensor the component from the second path and the electrical outputs of the CCDs combined to give an output video signal. In another embodiment, the optical outputs of the first and second paths are optically combined. In a shutter, for example, this combined output may then be applied to a single optical sensor, such as a single CCD sensor or camera tube. The optical paths must be adjusted such that when the outputs are combined, they are in register with one another. It may be useful for some devices to include a moveable reflective surface, such as a prism , within the device for adjustment of the paths relative to one another to permit correct registration to be obtained.

In a preferred embodiment of the invention, the polarising beam splitter and

birefringent cell means form part of a single component. The component may also incorporate an optical combiner in those embodiments where the optical outputs are combined. This is particularly advantageous as it enables the geometry of the device and the properties of the components to be selected during assembly and subsequently the single component may be handled, for example, for shipping or when assembling it into a larger arrangement whilst maintaining the correct alignments, removing the need for subsequent adjustments. The optical combiner may be a cube or a prism, for example. Where the device is included within, say, a camera in which a focussing lens system is used to focus the image onto the camera, the device may be incorporated in the focussing system, for example, being located between elements of the focussing system itself.

A device in accordance with the invention may be used as a switch which modulates the applied input radiation between on and off states only, or in other arrangements, the cell means may be controlled to produce an intermediate state or states, or a continuous gradient between states. Thus, in one advantageous embodiment, the cell means may be controlled so as to switch between a transmissive state, an off state and a single intermediate state. This is particularly suitable for those applications in which it is important to be able to switch from a fully transmissive state to a state in which a significant proportion of incoming radiation is blocked in a very short time, for example in a system which uses a laser to illuminate a scene, where it is necessary to protect an optical sensor from scattered laser radiation occurring in its close vicinity immediately subsequent to the generation of a laser pulse.

In a preferred embodiment, the optic axis or axes of the birefringent cell means are rotated in one path relative to those in the other path, permitting a wider acceptance angle for the device and also reducing or eliminating aliasing effects which might otherwise occur in those systems where the outputs are re-combined.

A device in accordance with the invention may be used to extract from a viewed scene details of either vertically or horizontally polarised components which occur in that scene.

Some ways in which the invention may be performed are now described by way of example with reference to the accompanying drawings, in which:

Figure 3 schematically illustrates an optical arrangement incorporating a device in accordance with the invention and having two CCD sensors;

Figure 4 schematically illustrates a cascaded parallel shutter in accordance with the invention;

Figure 5 schematically shows another arrangement in accordance with the invention having a single output;

Figure 6 schematically illustrates another device in accordance with the invention;

Figures 7, 8 and 9 are explanatory diagrams relating to the device of Figure 6; and

Figures 10, 11, 12 13 and 14 schematically show other devices in accordance with the invention.

With reference to Figure 3, a shutter arrangement includes a polarising beam splitter cube 1 at which unpolarised input radiation is received in the direction shown by the arrow. The cube 1 acts to split randomly polarised input light into two components, one being transmitted straight through the cube 1 to give a beam 2 which is linearly polarised with P-polarisation, and the other component being reflected through 90° to give an output beam 3 which is also highly polarised having a linear S-polarisation. The reflected beam 3 is applied to a prism 4 where it is redirected onto a first birefringent cell C1, the output of which is directed to an analyser, in this case an output polariser P2. This first optical path also includes a CCD sensor 5 arranged to receive the output from polariser P2. There is a second optical path through the system parallel to the first path which includes a second birefringent cell C2, a second output polariser P4 and a second CCD sensor 6. Any light incident on the CCD sensors 5 and 6 produces a charge pattern representative of the amount of radiation incident thereon which can be electronically read out and combined at combiner 7 to give a video output signal at 8.

When no optical field is applied to either of the cells C1 and C2, there is no change in the direction of polarisation of light transmitted therethrough and subsequently incident on output polarisers P2 and P4. Thus, substantially no optical radiation is incident on the CCD sensors 5 and 6. When an electrical field is applied to both cells C1 and C2, the resultant rotation of the linearly polarised output light is transmitted

through polarisers P2 and P4 to reach the CCD sensors 5 and 6. The outputs of the CCD sensors 5 and 6 are controlled to add inregistration so as to give a combined video output signal at 8. By using two parallel optical paths through the shutter, the transmission is effectively doubled compare to the simple optical shutter shown in Figure 1. In the arrangement shown in Figure 3, the transmission T_{ON}= (Ux P1 x C1 x P2) + (U x P1 x C2 x P4) which is approximately P1 x C1 x P2 giving a transmission of approximately 80%, U being 0.5 (being the conversion of unpolarised light to polarised light), P1 and P2 are both approximately 0.9 and the transmission of C1 is approximately 0.9.

The material used in the birefringent cells C1 and C2 is PLZT which is commercially available. The first and second cells C1 and C2 could be replaced by a single cell which is extensive across both optical paths.

With reference to Figure 4, a shutter in accordance with the invention includes the components of the device shown in Figure 3 and having the same reference numerals for clarity. In addition, the first optical path also includes a second birefringent cell C2 which uses PLZT and a second polariser P3 interposed between the first polariser P2 and the CCD sensor 5. The second optical path, which is parallel to the first, includes an additional birefringent cell C4, again of PLZT, and a second polariser P5 located in front of the CCD sensor 6. Again, the outputs of the CCDs 5 and 6 are combined at 7 to give a video output at 8. As in the Figure 3 embodiment, the polarising beam splitter cube 1 produces a transmitted beam of one polarisation and a reflected beam of another polarisation. Thus, again, instead of the transmission being

reduced by 50% at the first polariser, both beam components contribute to the final output signal. By using two cells in each of the parallel optical paths, the transmission, power requirements and speed of switching are improved compared to the Figure 3 device. In a variation of this configuration, the cells C1 and C3 are replaced by a larger single cell, and cells C2 and C4 are replaced by a second larger single cell.

With reference to Figure 5, a shutter in accordance with the invention has an input polarising beam splitter 1. Linearly polarised light reflected at 1 is transmitted along a first path via prism 4 to a first birefringent cell C_1 and passes via a combiner 8 to a CCD sensor 9. Light transmitted by the beam splitter 1 and polarised orthogonal to that in the first path is transmitted to a second cell C_3 and is then directed onto the combiner 8 by a second prism 10 where it is reflected and combined with light from the first path to give a single output to the CCD 9.

With reference to Figure 6 this shows another shutter in accordance with the invention which includes two parallel optical paths each of which incorporates cascaded birefringent cells. Input radiation is applied to the polarising beam splitter 1. The reflected component is transmitted via a first cell C_1 and onto a reflecting polariser P2 from whence it is directed onto a second C_2 and to a combiner 8 which includes a polariser 11, which acts as the analyser. The light is then incident on a single CCD camera 9. The transmitted component from beam splitter 1 is similarly directed via a cell C_3 ,a reflecting polariser P4 and a second cell C_4, being finally incident on a second reflecting polariser 11 where it is combined with the originally reflected

component to give a single output.

The device offers improved transmission enabling a TV camera to be used, for example, for pulsed laser viewing under total darkness conditions. In addition, the cells C_1, C_2, C_3 and C_4 may be operated so as to give a three-state transmission path between the input and the CCD display output. This is particularly useful for active laser cameras. When the laser is pulsed, there may be scattering close to the sensor from, say, the surrounding atmosphere. It is thus essential to effectively shield the sensor from outgoing laser emission. After a finite delay, useful image information must be extracted from a scene being viewed but this requires the transmission to be extremely good. Thus switching is achieved between maximum extinction of 10^{-4} during which time the laser fires, an intermediate extinction level of 10^{-2} and a maximum transmission state of approximately 70% during which received imagery is extracted. By controlling when voltages are applied to the cells C_1 to C_4, these three states may be achieved.

Figure 7 is an explanatory diagram concerning the generation of the three transmission states. Figure 7a shows the PLZT transfer function, giving the transmission achieved for a particular applied voltage, the three voltage levels being 400 volts, 500 volts and 700 volts. Figure 7b illustrates the temporal function of the PLZT material, showing transmission against response time.

For a particular situation where it is wished to block transmission during emission of a laser pulse but permit the laser return from the illuminated scene to pass through the

device, the transmissive states are as illustrated in Figures 8a, 8b and 8c. The laser pulse is emitted at time t1 shown at Figure 8a and the return received at time t2. Figure 8b shows the state of the shutter, which during time period a the shutter is fully off, at time c the shutter is fully on, being at maximum transmission, and at other times, the shutter is partially off, shown at d. The pulses shown in Figure 8b are ideal and those achievable using the device of Figure 6 and a three state drive are illustrated in Figure 8c, where it can be seen the rise and fall of the transmission level during laser emission t1 is about 5 microseconds duration and the fully on state occurs for approximately 1 microsecond.

Figure 9 schematically shows two cells C1 and C2 in series connected so as to achieve the three state drive. This is repeated for the other two cells C3 and C4 in the other optical path through the device.

In the arrangement shown in Figure 6, the digital electrodes laid down on the surfaces of the cells C_1 to C_4 are arranged so such that they are angled with respect to each other to avoid aliasing. In the Figure 6 arrangement, the angles of the electrodes of C_1 are + 22%, for C_2 + 45%, for C_3 - 22% and C_4 - 45%.

In the device of Figure 6, a control signal from the ccD 9 may be applied to the cells C1, C2, C3 and C4 to adjust transmission to ensure that the CCD 9 operates at optimum illumination levels. This may act, for example, to adjust for slowly varying ambient light conditions in a viewed scene.

The cells C1, C2, C3 and C4 may also be controlled so as to block transmission to the CCD 9 during frame intervals.

For each of the devices shown in Figures 3 to 6, it is possible to distinguish between vertically and horizontally polarised components of a viewed scene. For example, in the Figure 6 device, the vertical and horizontal polarised components in a scene may be separately viewed by firstly switching off C_3 and C_4 and viewing the scene transmitted via C_1 and C_2 and then switching off C_1 and C_2 and viewing via C_3 and C_4.

The device of Figure 6 may be modified by incorporating, for example, a blue pass filter in the first path and a red pass filter in the second path. For example, P2 may be a blue pass filter and P4 a red pass filter. Thus when the combined output is viewed, the colour present in the display will indicate the polarised states.

Colour separation may be achieved using a standard dichroic prism in which, say, blue light is reflected and red/green light is transmitted, or a triple colour dichroic arrangement in which light is separated into blue, red and green components.

The device shown in Figure 4 may also be used for polar viewing without the inclusion of optical colour filters. Colour can then be introduced by electrical processing.

Another embodiment of the invention is illustrated in Figure 10. This has an input

polar splitter 1 followed by a birefringent cell C1 and C2 in the respective reflected and transmitted paths. The light transmitted via cell C1 is reflected at P2 and is incident on a first CCD sensor 12. The transmitted light passes via cell C2 to a second CCD sensor 13. This arrangement avoids lateral inversion but involves unequal first and second path lengths.

Another device is illustrated in Figure 11 and includes a polar splitter 1 which divides the incident radiation. Light reflected at P1 is transmitted via a birefringent cell C1 to a reflective surface P2 followed by another surface P3 to a polar combiner 14 where it is combined with light transmitted via polar splitter 1 and a second birefringent cell C2, the combined output being received by a single CCD sensor 15.

With reference to Figure 12, another device includes a polar splitter 1 following which in each path is located a birefringent cell C1 and C2 the output of which is directed towards prisms 16 and 17, the light then being recombined at polar combiner 18 and the output directed towards a CCD sensor 19. The prism 17 is adjustable in position so as to enable precise adjustment of the light paths to be achieved. Thus, registration may be adjusted by moving one prism only. This device requires a single CCD only and also presents equal path lengths on both the first and second paths through the device.

With reference to Figure 13, another device includes two polarising cubes and two polarisers. One cube acts as a polar splitter 1 and the second cube as a combiner 20. Two prisms 21 and 22 are located in the first and second optical paths and birefringent

cells C1, C2, C3 and C4 are located between the cubes and prisms. In addition, two polarisers P1 and P2 are incorporated in the first and second optical paths.

With reference to Figure 14a, a device 23 similar to that shown in Figure 13 is located as a shutter between an input lens 24 and a CCD 25. The insertion of device 23 results in a longer system compared to an arrangement in which the device 23 is absent as illustrated in Figure 14b. In this arrangement the entry cube 1 of the device 23 is longer than the exit cube 20 because of the acceptance angle which is aperture and focal length dependent.

CLAIMS

1. An electro-optic device comprising: a polarising beam splitter which produces first and second differently polarised components from applied unpolarised optical radiation; first and second optical paths along which the first and second components respectively are directed; and birefringent cell means in the first and second paths.

2. A device as claimed in Claim 1 wherein the cell means comprises a first cell in the first path and a second different cell in the second path.

3. A device as claimed in Claim 1 or 2 wherein the cell means comprises a single cell which is included in both the first and second paths, the first and second components being applied to different regions of the single cell.

4. A device as claimed in Claim 1, 2 or 3 wherein the cell means is independently controllable in the first and second paths.

5. A device as claimed in any preceding claim wherein the cell means includes a plurality of birefringent cells in the first path and plurality of birefringent cells in the second path.

6. A device as claimed in any preceding claim wherein the optical outputs of the first and second paths are kept separate.

7. A device as claimed in any of Claims 1 to 5 wherein the optical outputs of the first and second paths are combined.

8. A device as claimed in any preceding claim and including optical sensor means arranged to receive the components after they have travelled along the first and second paths.

9. A device as claimed in Claim 8 wherein the optical sensor means includes CCD means.

10. A device as claimed in Claim 8 or 9 when dependent on Claim 6, wherein the outputs of the first and second optical paths are applied to respective different optical sensors and the outputs of the sensors subsequently combined.

11. A device as claimed in any preceding claim and including analyser means to receive the output of the birefringent cell means.

12. A device as claimed in any preceding claim wherein the beam splitter comprises a polarising beam splitter cube.

13. A device as claimed in any preceding claim wherein the birefringent cell means includes PLZT.

14. A device as claimed in any preceding claim wherein electrodes incorporated in

the cell means in one optical path are offset with respect to electrodes in the cell means in the other optical path.

15. A device as claimed in any preceding claim wherein the cell means is operable such as to produce three or more degrees of transmission through the device.

16. A device as claimed in any preceding claim wherein the birefringent cell means is controlled to maintain the optical output of the device within a pre-determined range during transmission.

17. a device as claimed in claim 16 and including a sensor for monitoring the output and means for deriving a control signal dependent on the monitored output and applying it to the birefringent cell means.

18. A device as claimed in any preceding claim wherein the birefringent cell means is controlled to prevent transmission during frame intervals of a sensor which receives the optical output.

19. A device as claimed in any preceding claim wherein at least the beam splitter and birefringent cell means are parts of a single component.

20. A device as claimed in Claim 19 when dependant on Claim 7 wherein an optical combiner for combining first and second components after transmission through the cell means forms part of the single component.

21. A device as claimed in any preceding claim wherein first and second polarised components are output in respective different colours.

22. A device as claimed im any preceding claim wherein the optic axis of the birefringent cell means in one path is rotated relative to that in the other path.

23. Camera apparatus including a device as claimed in any preceding claim.

24. Camera apparatus as claimed in Claim 23 wherein the device is included within the focussing system of the camera.

25. An electro-optic device substantially as illustrated in and described with reference to any one of Figures 3 to 14 of the accompanying drawings.

26. A shutter arrangement substantially as illustrated in and described with reference to any one of Figures 3 to 14 of the accompanying drawings.

Fig.1.

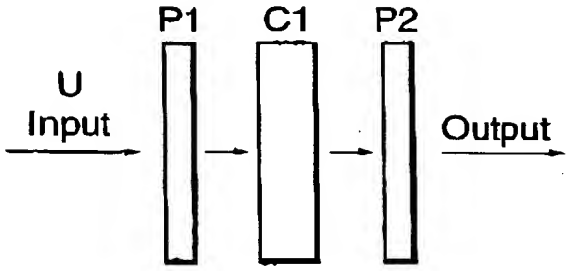

Fig.2.

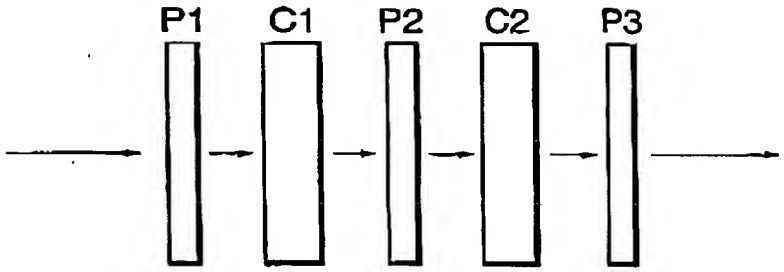

Fig.3.

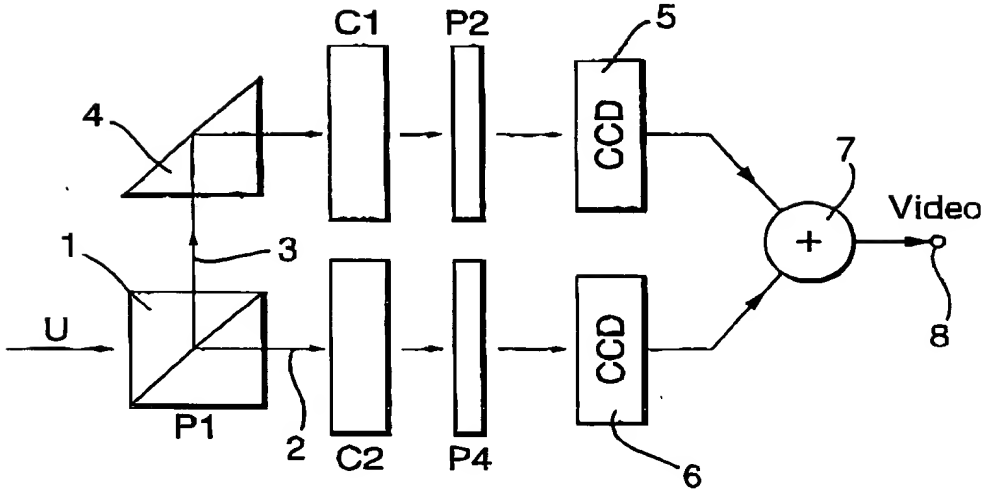

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Fig.4.

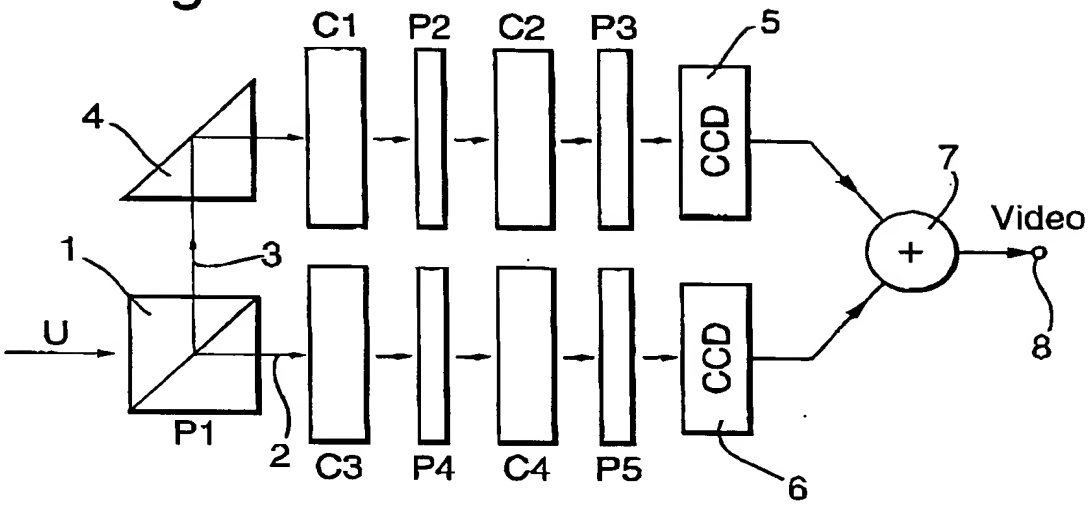

Fig.5.

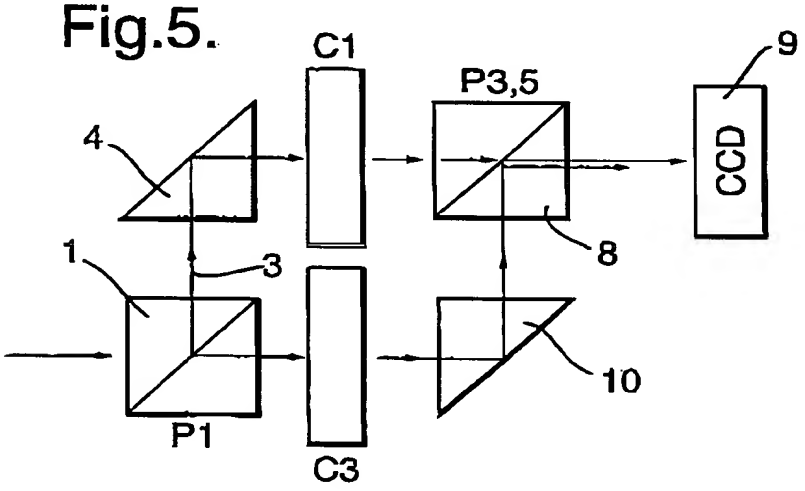

Fig.6.

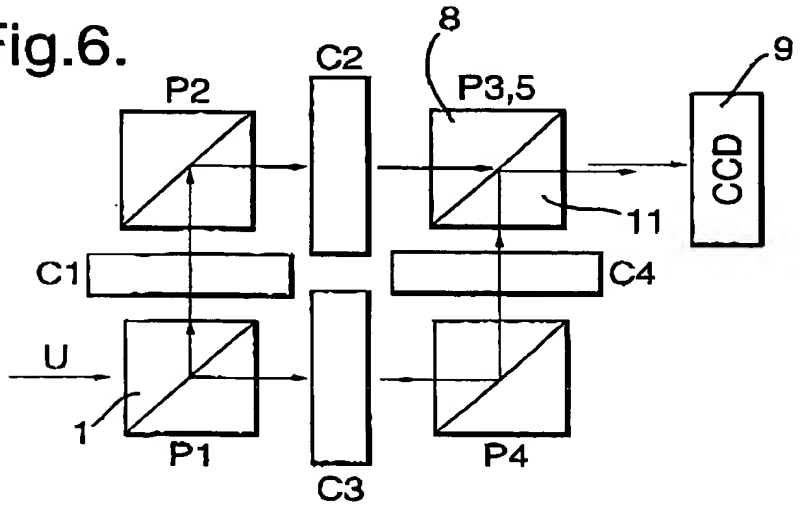

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Fig.7a.

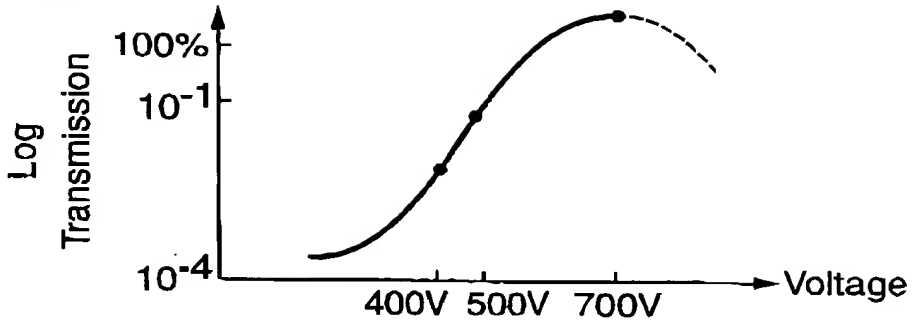

Fig.7b.

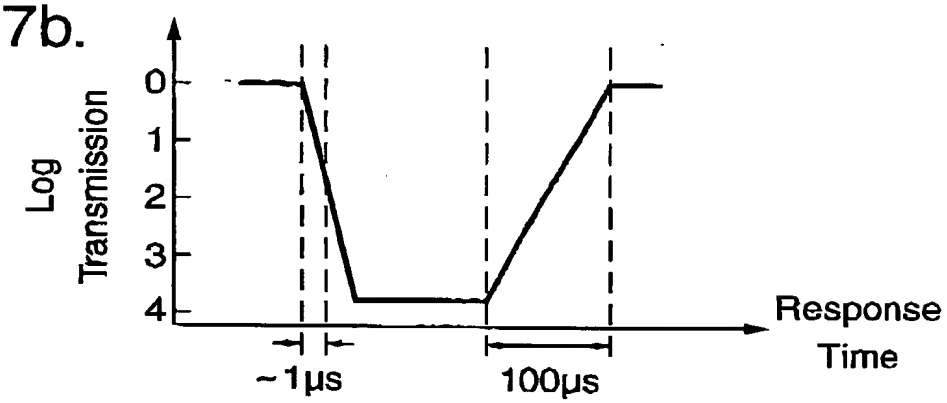

Fig.8a.

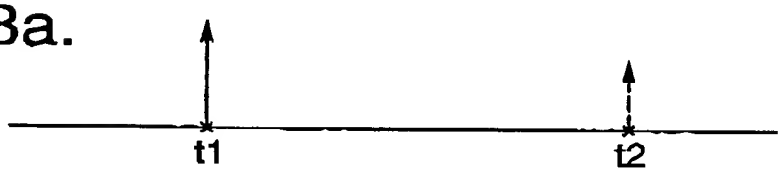

Fig.8b.

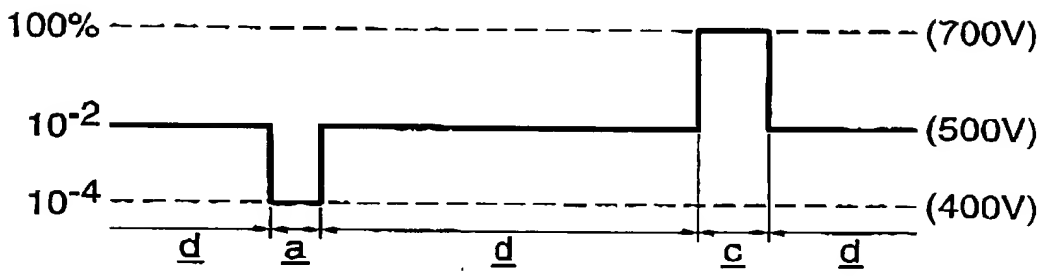

Fig.8c.

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Fig.9.

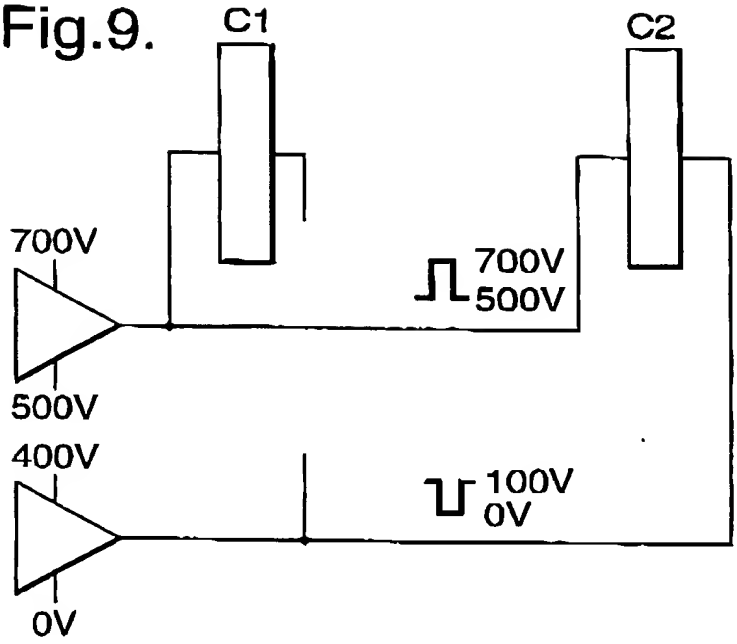

Fig.10.

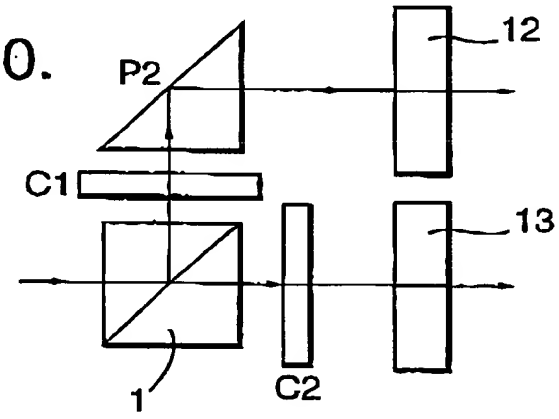

Fig.11.

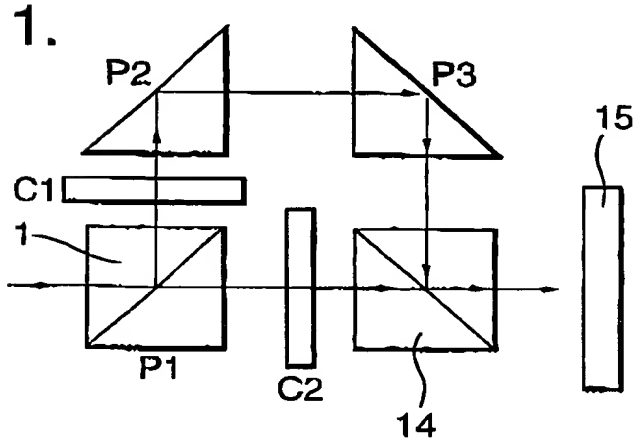

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Fig.12.

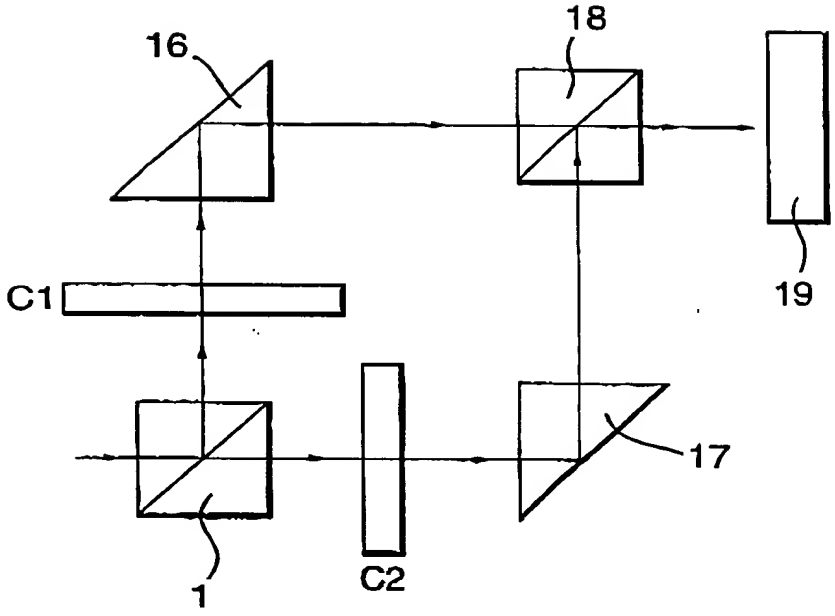

Fig.13.

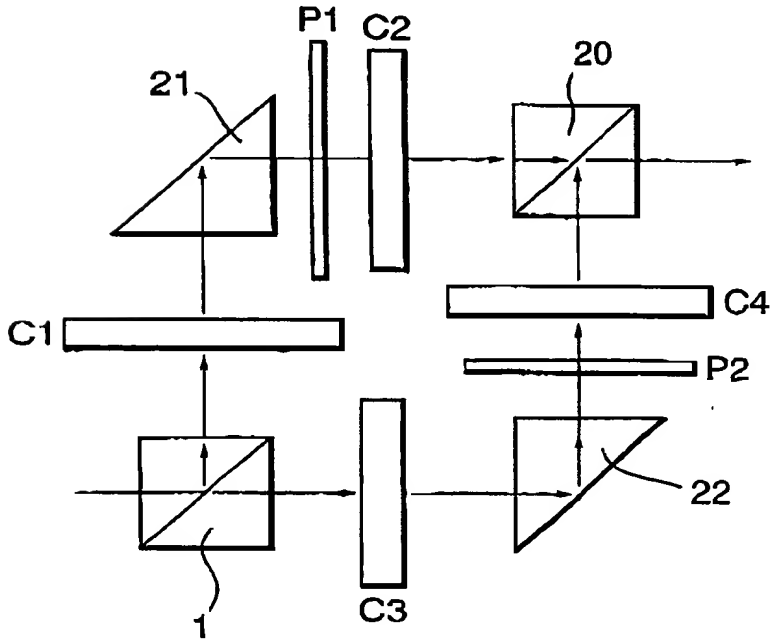

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Fig.14a.

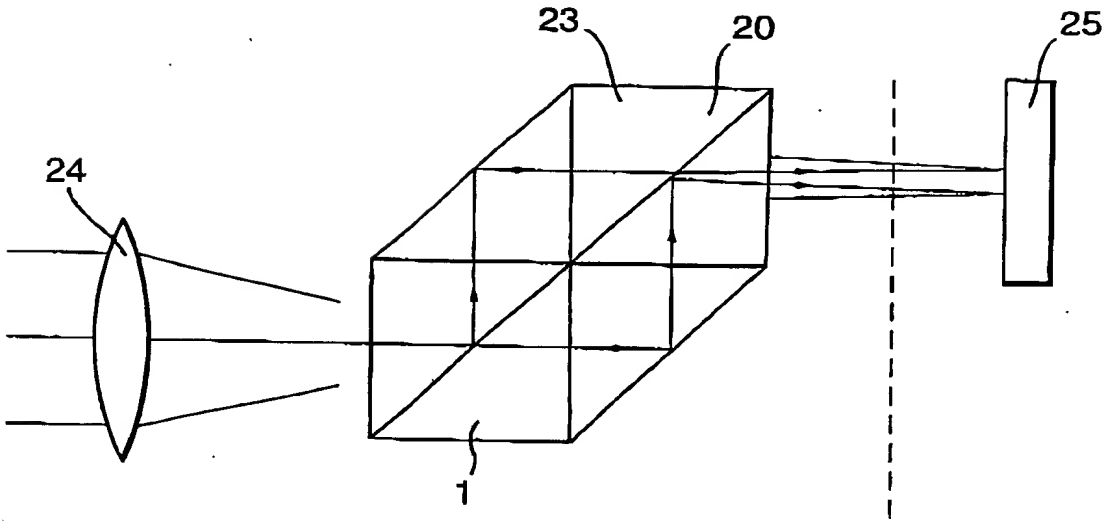

Fig.14b.